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Schreiber Translations, Inc.

51 Monroe Street

Suite 101

Rockville, MD 20850

P: 301.424.7737

F: 301.424.2336

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Editor
Schreiber Translations, Inc.
51 Monroe Street, Suite 101
Rockville, Maryland 20850

translation@schreibernet.com

www.schreibernet.com

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(71) Applicant 000165963
Furukawa Aluminum Co., Ltd..
1-gō, 6-ban, 2-chōme, Marunouchi,
Chiyoda-ku, Tokyo

(72) Inventor Kunihiko KISHINO
Furukawa Aluminum Co., Ltd..
1-gō, 6-ban, 2-chōme, Marunouchi,
Chiyoda-ku, Tokyo

(72) Inventor Motohiro NABAE
Furukawa Aluminum Co., Ltd..
1-gō, 6-ban, 2-chōme, Marunouchi,
Chiyoda-ku, Tokyo

(72) Inventor Kenji OGURA
Furukawa Aluminum Co., Ltd..
1-gō, 6-ban, 2-chōme, Marunouchi,
Chiyoda-ku, Tokyo

(57) [Abstract]

[Object] [To provide] an aluminum alloy clad material with good strength and with good high temperature formability suitable for product members employed in a marine atmosphere, such as ships.

[Configuration] A high-strength aluminum alloy clad material for high-temperature forming comprising a core in the form of an Al alloy comprising 2-7.5 weight percent of Mg, one or more selective elements chosen from among Cr, Mn, Zr, Ti, Fe, Ni, Cu, and Zn, and a cladding material in the form of an Al alloy comprising 1-2 percent MgO, not more than 1 percent Fe, not more than 1 percent Si, and one or more selective elements in the form of Cu, Zn, Cr, Mn, Zr, and Ni , where one or both sides of the core material are clad.

[Claims]

[Claim 1] A high-strength aluminum alloy clad material for high-temperature forming characterized by one or both sides of a core material comprising a necessary element in the form of 2-7.5 weight percent of Mg and selectively containing one or more selected from among 0.03-0.55 weight percent of Cr, 0.03-2.5 weight percent of Mn, 0.03-0.25 weight percent of Zr, 0.005-0.35 weight percent of Ti, 0.03-0.5 weight percent of Fe, and 0.03-1.5 weight percent of Ni, the remainder being of Al, is clad with a cladding material

comprising 0.1-2 weight percent of Mg, not more than 1 weight percent of Si, and not more than 1 weight percent of Fe, with the remainder being Al.

[Claim 2] A high-strength aluminum alloy clad material for high-temperature forming characterized in that one or both sides of a core material comprising a necessary element in the form of 2-7.5 weight percent of Mg and selectively containing one or more selected from among 0.03-0.55 weight percent of Cr, 0.03-2.5 weight percent of Mn, 0.03-0.25 weight percent of Zr, 0.005-0.35 weight percent of Ti, 0.03-0.5 weight percent of Fe, and 0.03-1.5 weight percent of Ni, the remainder being of Al, is clad with a cladding material comprising 0.1-2 weight percent of Mg, not more than 1 weight percent of Si, and not more than 1 weight percent of Fe, and selectively comprising one or more selected from among 0.1-1 weight percent of Cu, 0.1-1.0 weight percent of Cr, 0.1-0.3 weight percent of Zr, and 0.1-1.5 weight percent of Ni, with the remainder being aluminum.

[Claim 3] A high-strength aluminum alloy clad material for high-temperature forming characterized in that one or both sides of a core material comprising a necessary element in the form of 2-7.5 weight percent of Mg; containing one or both from among 0.01-0.5 weight percent of Cu and 0.02-2.5 weight percent of Zn; and selectively containing one or more selected from among 0.03-0.55 weight percent of Cr, 0.03-2.5 weight percent of Mn, 0.03-0.25 weight percent of Zr, 0.005-0.35 weight percent of Ti, 0.03-0.5 weight percent of Fe, and 0.03-1.5 weight percent of Ni, the remainder being of Al, is clad with a cladding material comprising 0.1-2 weight percent of Mg, not more than 1 weight percent of Si, and not more than 1 weight percent of Fe, with the remainder being aluminum.

[Claim 4] A high-strength aluminum alloy clad material for high-temperature forming characterized in that one or both sides of a core material comprising a necessary element in the form of 2-7.5 weight percent of Mg; containing one or both from among 0.01-0.5 weight percent of Cu and 0.02-2.5 weight percent of Zn; and selectively containing one or more selected from among 0.03-0.55 weight percent of Cr, 0.03-2.5 weight percent of Mn, 0.03-0.25 weight percent of Zr, 0.005-0.35 weight percent of Ti, 0.03-0.5 weight percent of Fe, and 0.03-1.5 weight percent of Ni, the remainder being of Al, is clad with a cladding material comprising 0.1-2 weight percent of Mg, not more than 1 weight percent of Si, and not more than 1 weight percent of Fe, and selectively comprising one or more selected from among 0.1-1 weight percent of Cu, 0.1-1.0 weight percent of Cr, 0.1-0.3 weight percent of Zr, and 0.1-1.5 weight percent of Ni, with the remainder being aluminum.

[Detailed Description of the Invention]

[0001]

[Industrial Field of Application] The present invention relates to an aluminum alloy clad material of good formability and strength, formed by high-temperature forming followed or not followed by surface treatment, and more particularly, to product members suited to use in marine atmospheres, such as ships.

[0002]

[Prior Art and Its Problems] Steel plates which are formed by pressing and then painted are often used as external plating in the hulls of ships such as comparatively small fishing vessels and leisure boats. However, since steel plates have low corrosion resistance once the paint is scratched or peels off and must be regularly repainted, the number of ships employing FRP hulls has increased sharply in recent years. Since scrap processing of ships with FRP hulls that have reached the end of their service lifetimes is

difficult, an environmental pollution problem is currently developing due to the abandoning of scrap vessels along the coastline and the like.

[0003]

[Problems to Be Solved by the Invention] Given the above-described situation, aluminum plating, which has better corrosion resistance than steel plating and lends itself better to scrap processing and recycling than FRP, is attracting attention as a structural material for ship hulls. Al-Mg alloys, with their good corrosion resistance, strength, and formability, are often employed as structural members exposed to such maritime atmospheres. However, aluminum structural materials generally tend to have poorer formability than steel plating, which has proven an impediment in determining the shape of products. Accordingly, warm forming and high-temperature forming are being investigated as techniques of forming aluminum plating into more complex shapes. These techniques involve heating the material and part or all of the die to 100-500°C to conduct forming under conditions at which the formability of the material is enhanced, and are suited to the forming of members requiring a high level of processing. Further, in high temperature forming, bulge forming employing pneumatic or hydraulic pressure in addition to the usual press processing is also being examined. This method is advantageous in that a male die is not needed because pneumatics or hydraulics are employed as the pressurizing medium, and in that forming limits are raised because the material is uniformly transformed. However, when the above-mentioned Al-Mg alloys are high-temperature formed, the Mg atoms at the surface concentrate and oxidize into a greenish black color that is undesirable in appearance. When applying paint, as well, the oxidation layer decreases adhesion of the paint film, resulting in deterioration of product resistance to corrosion. It is necessary to chemically or mechanically remove such oxide films, which is an impediment to production. The formation of the oxide film is affected by temperature and processing time. However, it is often a problem in press forming with a hydraulic press and bulge processing, where the formation rate is rather slow. In light of these problems, the present invention has been developed as a corrosion-resistant aluminum alloy clad material for high-temperature forming that is suited to use in members such as the outer plates of comparatively small ship hulls that are formed at high temperature.

[0004]

[Means of Solving the Problems] The first claim of the present invention is a high-strength aluminum alloy clad material for high-temperature forming characterized in that one or both sides of a core material comprising a necessary element in the form of 2-7.5 weight percent of Mg and selectively containing one or more selected from among 0.03-0.55 weight percent of Cr, 0.03-2.5 weight percent of Mn, 0.03-0.25 weight percent of Zr, 0.005-0.35 weight percent of Ti, 0.03-0.5 weight percent of Fe, and 0.03-1.5 weight percent of Ni, the remainder being of Al, is clad with a cladding material comprised of 0.1-2 weight percent of Mg, not more than 1 weight percent of Si, not more than 1 weight percent of Fe, with the remainder being aluminum. The second claim is a high-strength aluminum alloy clad material for high-temperature forming characterized in that one or both sides of a core material comprising a necessary element in the form of 2-7.5 weight percent of Mg and selectively containing one or more selected from among 0.03-0.55 weight percent of Cr, 0.03-2.5 weight percent of Mn, 0.03-0.25 weight percent of Zr, 0.005-0.35 weight percent of Ti, 0.03-0.5 weight percent of Fe, and 0.03-1.5 weight

percent of Ni, the remainder being of Al, is clad with a cladding material comprising 0.1-2 weight percent of Mg, not more than 1 weight percent of Si, not more than 1 weight percent of Fe, and selectively comprising one or more selected from among 0.1-1 weight percent of Cu, 0.1-1.0 weight percent of Cr, 0.1-0.3 weight percent of Zr, and 0.1-1.5 weight percent of Ni, with the remainder being aluminum. The third claim is a high-strength aluminum alloy clad material for high-temperature forming characterized in that one or both sides of a core material comprising a necessary element in the form of 2-7.5 weight percent of Mg; containing one or both from among 0.01-0.5 weight percent of Cu and 0.02-2.5 weight percent of Zn; and selectively containing one or more selected from among 0.03-0.55 weight percent of Cr, 0.03-2.5 weight percent of Mn, 0.03-0.25 weight percent of Zr, 0.005-0.35 weight percent of Ti, 0.03-0.5 weight percent of Fe, and 0.03-1.5 weight percent of Ni, the remainder being of Al, is clad with a cladding material comprising 0.1-2 weight percent of Mg, not more than 1 weight percent of Si, not more than 1 weight percent of Fe, with the remainder being aluminum. And the fourth claim is a high-strength aluminum alloy clad material for high-temperature forming characterized in that one or both sides of a core material comprising a necessary element in the form of 2-7.5 weight percent of Mg; containing one or both from among 0.01-0.5 weight percent of Cu and 0.02-2.5 weight percent of Zn; and selectively containing one or more selected from among 0.03-0.55 weight percent of Cr, 0.03-2.5 weight percent of Mn, 0.03-0.25 weight percent of Zr, 0.005-0.35 weight percent of Ti, 0.03-0.5 weight percent of Fe, and 0.03-1.5 weight percent of Ni, the remainder being of Al, is clad with a cladding material comprising 0.1-2 weight percent of Mg, not more than 1 weight percent of Si, not more than 1 weight percent of Fe, and selectively comprising one or more selected from among 0.1-1 weight percent of Cu, 0.1-1.0 weight percent of Cr, 0.1-0.3 weight percent of Zr, and 0.1-1.5 weight percent of Ni, with the remainder being aluminum.

[0005]

[Operation] The reasons for limiting the alloy components in the present invention are described below. First, the alloy composition of the core material will be described. Mg has the effect of improving formability by forming a solid solution in the material, thereby increasing the strength and ductility of the material. Mg has the effect of promoting uniform transformation while the material is forming, especially when it is heated to an elevated temperature. It has the effects of increasing the static strength of the product, preventing deformation due to external forces, and preventing changes over time (creep deformation and the like) when the hull or the like is subjected to long-term external pressure. Further, the products contemplated by the present invention also have increased resistance to corrosion when untreated, such as when the cladding or the like is scratched by environmental factors. When the quantity added is less than 2 weight percent, the effect is inadequate, and when 7.5 weight percent is exceeded, coarse Al-Mg compounds form in the material, compromising formability and corrosion resistance. Cu and Zn form minute compounds with Mn in the material, having the effect of improving formability by improving product strength and ductility. However, with both elements, the corrosion resistance of the material tends to decrease somewhat, so it is desirable to consider the shape and the use of environment in deciding whether or not to add both elements to products in which the corrosion resistance of the core is an issue. Improvement in formability cannot be expected when the quantity added is below the lower limit for each of the elements. When added in quantities exceeding the upper limit,

corrosion resistance drops precipitously. Cr, Mn, Zr, Ti, Fe, and Ni each form minute compounds with Al in the material, refining the material texture to increase strength and formability, and improving the resistance to corrosion of the material. Accordingly, it is necessary to selectively add one or more of these elements. When the quantity added is less than the lower limit, the effects achieved are inadequate, and when added in quantities exceeding the upper limit, coarse compounds form in the material and formability deteriorates. Si is the chief impurity element incorporated in addition to the above elements. During casting of the alloy, Si forms Mg-Si compounds with the Mg, thereby decreasing the amount of Mg that is actually added and diminishing the effect, as well as compromising corrosion resistance. Thus, a low Si content is desirable. However, decreasing the quantity of Si means high purification of the base metal employed. Since this entails higher manufacturing costs, it is not desirable from an industrial perspective to decrease the Si content more than is necessary. Based on these factors, the Si content is 0.5 weight percent or less. A content of 0.5 weight percent or less for each of the other trace elements does not negatively affect the characteristics of the present invention. Accordingly, trace metals such as Be and B, which are added to improve castability, and misch metals, added to improve formability, can be added in a range of 0.05 weight percent or less. Nor does it matter if other elements mixed in during manufacturing comprise 0.5 weight percent or less.

[0006] Cladding alloy components will be described next. From the perspective of oxide film formation, a low quantity of Mg in the cladding is desirable; however, Mg has the effects of improving the high-temperature strength and formability at high temperature of the material. When the quantity of Mg is less than 0.1 weight percent, strength and formability are inadequate. When the quantity of Mg exceeds 2 weight percent, the formation of oxide film during high temperature forming becomes severe. Fe and Si are the main impurities incorporated. However, when these two are each incorporated at greater than 1 weight percent, a coarse crystalline product forms in the material, compromising formability and corrosion resistance. Thus, the content of these elements is 1 weight percent or less. Cu, Cr, Zr, and Ni have the effect of improving the formability of the material at high temperature. At less than the lower limit of these elements, the effect is inadequate, and when added in quantities exceeding the upper limit, there is the risk that formability will decrease. However, since these elements sometimes reduce resistance to corrosion somewhat in the use environment, it is necessary to decide whether or not to add them based on need. Other elements can be mixed in during manufacturing in a quantity of 0.5 weight percent or less without negatively affecting the characteristics of the material of the present invention. The clad material of the present invention can be manufactured by the usual methods.

[0007]

[Embodiments] Embodiments of the present invention are described below. Core and cladding material alloys having the chemical compositions shown in Table 1 were DC cast into blocks 400 mm thick and 2,300 mm in width. In the case of the cladding material, 5mm was shaved off each of two surfaces of the cast blocks, they were subjected to a homogenizing treatment at 600°C for 8 hr, hot rolled, and then cold rolled to form 10 mm plates. In the case of the core material, 10 mm was shaved off each of two

surfaces of the cast blocks and they were combined with cladding material into a 400 mm combined material and subjected to a homogenizing treatment at 440°C for 6 hr and 520°C for 8 hr. The combined material was then hot rolled and cold rolled by the usual methods to a clad material 1 mm in thickness. This sheet material was then annealed at 500°C for 10 sec to obtain test material. The unclad material in the comparative examples was prepared by subjecting 380 mm cast blocks after surface shaving to the same homogenizing treatment, hot rolling, cold rolling, and annealing treatment as the clad material to obtain test material 1 mm thick. Test blocks 400 x 400 mm were processed out of the sheet material obtained for use in the warm punch stretch forming test. In the warm punch stretch forming test, ball-headed punches 200 mm in diameter were employed for forming at 450°C and the formation limit height at which cracking did not occur was obtained. The forming rate was a punch displacement speed of 1 mm/sec. The degree of discoloration of the material surface following forming was checked by visual observation of the external appearance. The results are given in Table 1. Tension test blocks were also processed from the test material. As a simulation of heating during high temperature forming, the blocks were heated at 450°C for 5 min, cooled to ordinary temperature, and post-heating strength was evaluated with a tension test. The results are given in Table 1.

[0008]

[Table 1]

	No.		Chemical Composition (wt %)											Punch stretch height mm	Appearance after heating	Strength after heating kgf/mm^2	
			Mg	Cu	Zn	Cr	Mn	Zr	Ti	Fe	Ni	Si	Al			Tensile strength	Yield strength
Embodiments of present invention	1	core	4.5	-	-	-	-	-	0.001	0.02	-	0.03	Remainder	90	No discoloration	30.1	15.1
		cladding	1.5	-	-	-	-	-	-	0.12	-	0.09	"				
	2	core	6.2	-	0.29	-	-	0.13	0.029	0.08	0.32	0.17	"	98	No discoloration	36.1	17.2
		cladding	1.5	-	-	-	-	-	-	0.12	-	0.09	"				
	3	core	2.6	0.35	-	0.12	0.65	-	0.022	0.18	-	0.10	"	79	No discoloration	28.9	9.9
		cladding	1.2	0.78	-	0.14	-	-	-	0.18	0.33	0.09	"				
	4	core	5.2	-	-	0.15	-	-	0.018	0.05	-	0.06	"	93	No discoloration	32.9	19.1
		cladding	0.7	-	-	0.21	-	0.15	-	0.21	0.78	0.13	"				
	5	core	4.9	0.42	2.1	0.15	-	0.12	0.012	0.10	-	0.11	"	92	No discoloration	34.1	20.1
		cladding	0.7	-	-	0.21	-	0.15	-	0.21	0.78	0.13	"				
Comparative examples	6	core	4.5	-	-	-	-	-	0.001	0.02	-	0.03	"	89	Entire surface became blackish brown	30.9	15.4
		cladding	Not clad														
	7	core	1.5	0.33	2.0	-	0.52	-	0.010	0.18	-	0.09	"	55	No discoloration	12.1	6.8
		cladding	0.7	-	-	0.21	-	0.15	-	0.21	0.78	0.13	"				
	8	core	9.9	-	-	-	-	-	0.010	0.10	-	0.07	"	65	No discoloration	39.1	22.8
		cladding	0.7	-	-	0.21	-	0.15	-	0.21	0.78	0.13	"				
	9	core	4.9	0.42	2.1	0.15	-	0.12	0.012	0.10	-	0.11	"	91	Entire surface became brown	33.9	19.5
		cladding	2.9	0.58	-	0.12	-	-	-	0.15	-	0.09	"				
	10	core	2.6	0.35	-	0.12	0.65	-	0.022	0.18	-	0.10	"	77	No discoloration	25.2	7.9
		cladding	0.05	-	-	-	-	-	-	0.05	-	0.06	"				

[0009] As is evident from the table, the aluminum alloy clad material of the present invention did not discolor even when formed at high temperature and had good warm formability and good strength after heating, in contrast to the comparative examples.

[0010]

[Effect of the Invention] The present invention exhibits good warm forming properties and high strength after heating, is characterized by not having drawbacks such as surface discoloration after processing, and exhibits market industrial effects.